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Fuzzy Soft Set Based Multiobjective Fuzzy Transportation Problem Involving Carbon Emission Cost Linked With The Travelling Distance

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ABSTRACT:

Each day, the actuality in the global shipment process creates numerous challenges for the marketing channels. A flawless and profitable forethought is demanded every time owing to the non-deterministic behaviour of supply, demand, cost, time etc. The major characteristics of transport including the service characteristics, modes of transport, traffic characteristics have a greater influence in the supply chain. The ignorance of such parameters mask the differences in the demand and distribution of commoditiescausing a loss in the business. Such a difficulty can be managed with the use of soft sets which considers the decision makers desired parameters and figure out the ambiguity in them. Fuzzy set theory is merged with soft sets to deal with imprecise or vague data corresponding to each parameter.In this paper, a fuzzy soft set based model is investigated to resolve the multi-objective fuzzy transportation problem with parametric ambiguity. Also, in the recent times transportation systems have reported greater impacts on the environment and so it is necessary keep down the global greenhouse gas emissions from the trade and commerce. Thus, a case study with transportation cost, transportation time and carbon emission cost for the travelling distancewith respect to three different modes of transport is cumulated and the proposed model is vindicated.Finally, it is solved using FuzzyProgramming approach(FPA), Intutionistic Fuzzy Programming Approach(IFPA) and Pythagorean Fuzzy Programming Approach(PFPA) in LINGO(19.0) and the results are concluded.

KEYWORDS: Fuzzy soft set, multi-objective transportation, carbon emission cost, Pythagorean trapezoidal fuzzy number, optimal compromise solution.

1.INTRODUCTION:

Transportation problem is a particular kind of linear programming problem where the intention is to cut down the cost (or) time taken to transport the given material from number of sources to number of terminuses. Researchers have developed various techniques and procedures to fathom the hurdles in transportation problem. Single objective transportation problems are inadequate for the rapidly expanding business world and so transportation problem with multiple objectives are studied. Later, to facilitate faster and more efficient movement of cargo, multiple modes of transport are taken into consideration whichhelps in the growth of the supply chain. The variability in the transportation parameters because of inadequate information, flawed statistical survey, oscillating markets etc. engendered theories of fuzzy set, probability, randomness, rough sets and so on in the transportation sector. To clear up the ambiguity in supply and demand, Stephen Chanas[5] analysed the transportation problem with crisp cost and fuzzy supply and demand.Fuzzy Set theory was introduced by Zadeh.L.A[16]which assigned a degree to certain object in the set. Waiel[13] presented a fuzzy programming approach to themulti-objective transportation problem.Kaur.A[8]represented the transportation parameters as generalized trapezoidal fuzzy numbers and clarified the problem with a new method which is a straight adjunct of the classical technique.Zangiabadi.M and Maleki.H.R[17] presented a fuzzy goal programming approach for solving a multi-objective transportation problem. Roy.S.K, G.Maity, G.W.Weber[12] formulated the mathematical model of two stage multi-objective transportation problem where grey parameters are incorporated for supply and demand and a solution is found with a new algorithm and with revised multi-choice goal programming approach. Generally,the elucidation of any object has inexhaustible conditions. The theory of soft sets byMolodtsov.D[11]grants the mathematician to go for the parameters of choice to deal with variability in a better way. The theory of soft sets is widely used in the decision making problems. Yuksel.S [15] discussed the usage of soft expert system to diagnose the patient with prostate cancer. Maji.P.K et al[9] introduced the concept of fuzzy soft sets which is a blend of soft set and fuzzy set theory. In fuzzy soft set, a membership degree is attached with each element in the corresponding value set of the desired parameter. This makes fuzzy soft set more precise to decision making. An extension of fuzzy set called the intutionistic fuzzy set was given by Atanassov.K.T[3] which characterised two functions called the degree of membership and degree of non-membership thereby providing a more detailed value for the uncertain data. Yager and Abbasov[14]scrutinized the drawbacks of intutionistic fuzzy set with Pythagorean fuzzy set in countless reality problems. Adami.A.Y[1] proposed a strategy on Pythagorean hesistant fuzzy computational algorithm to solve an ambiguous transportation problem. Over the last few years, environment consciousness is the aspiration for many developed and developing countries which evokes a significant environmental goal for companies and trading sectors.Carbon dioxide emissions are the primary source of global climate change. In the second half of the 20^{th} century, there is a rise in emissions especially across the Asian countries and so many countries have opted for pricing the emission of carbon. Majority of the countries have already implemented Emission Trading Systems and Carbon Tax while many are planning to device them in future. The implementation of this kind of strategy in India can result in the economic development along with a healthy green environment. Aishwarya.R[2] applied the fuzzy goal programming technique to minimize the travel time and emission cost due to traffic congestion contributing to a green environment.Vijayalakshmi. P[10] investigated a fully fuzzy fractional capacitated multi-objective solid transportation problem with emission related to diesel and blended fuel so as to shut out environmental degradation.

In this paper, an attempt has been made to solve a environmentally responsible fuzzy soft multi-objective fuzzy transportation problem where transportation cost, transportation time and carbon emission cost are taken asPythagorean Trapezoidal fuzzy numbers. Here, the desired parameters are the three modes of transportation (ie,road,rail and air). The secondary databases for the transportation time and transportation cost are assembled from G.Sharma and V.Sharma[6] in which a soft transportation model is exemplified for decision making in the transportation environment. Meanwhile, the carbon emission cost for the distance travelled is computed from the fuel consumption standards for heavy duty vehicles in the Gazette of India[4] and from the carbon emission factors estimated by the India GHG Programme for material transport in the Indian Railways and Airways[7]

The organisation of the paper is as follows. In section 2, the preliminaries are given. In section 3, the mathematical formulations and the different solution approaches of the transportation problem are provided. In section 4, a case study is elaborated and the optimal compromise solutions are found using Lingo(19.0). Section 5 concludes the paper.

2. PRELIMINARIES:

Definition 2.1. Let U be the universe of discourse and M be the membership space containing the closed real interval [0,1]. Then the fuzzy set $\widetilde{A}$ in U is the set of all ordered duo

$\widetilde{A} = \{(u, \mu_{\widetilde{A}}(u))/u \epsilon U\}$,

where $\mu_{\widetilde{A}}(u)$ is a mapping from U to M and is called the degree of membership.

Definition 2.2. The trapezoidal fuzzy number K* = (p,q,r,s) is defined as

$$\mu_{k^*}(u) = \begin{cases} \dfrac{u-p}{q-p} & p \le u < q \\ 1 & q \le u < r \\ \dfrac{s-u}{s-r} & r \le u < s \\ 0 & otherwise \end{cases}$$

Definition 2.3. Let U be the universe of discourse. Then, a Pythagorean fuzzy set $\widetilde{A}$ in U is the set of ordered trio

$\widetilde{A} = \{(u, \mu_{\widetilde{A}}(u), \vartheta_{\widetilde{A}}(u))/u\epsilon U,$

where $\mu_{\widetilde{A}}(u): U \rightarrow [0,1]$ denotes the membership degree and $\vartheta_{\widetilde{A}}(u): U \rightarrow [0,1]$ denotes the non-membership degree satisfying the condition $0 \leq \mu_{\widetilde{A}}(u)^2 + \vartheta_{\widetilde{A}}(u)^2 \leq 1$.

Definition 2.4. Let U be the universal set and E be the set of parameters. Let A ⊂ E. Then, the duo (F,A) is called the soft set where F is a mapping from A to$\wp(U)$

$$(F, A) = F(A) = \{F(e_1), F(e_2), \ldots\ldots, F(e_n)\}$$

Here, $F(e_i)$ is called the value set concerning the parameter e_i. To be specific, soft set is a parameterised descent of the subsets of the universe.

Definition 2.5. Let U be the universal set and E be the set of parameters. A duo (F,A) is called a fuzzy soft set when F is a mapping from A to $\widetilde{\wp(U)}$. In general, fuzzy soft set is a parameterised family of fuzzy subsets of the universe.

Definition 2.6. Let $\tilde{\alpha} = ((p, q, r, s), (\mu, \vartheta))$ be a Pythagorean Trapezoidal Fuzzy number. Then, its score function is

$S(\tilde{\alpha}) = \frac{p+q+r+s}{4}(\mu^2 - \vartheta^2)$ where $(\mu^2 - \vartheta^2) \in [-1,1]$.

3.1. MATHEMATICAL FORMULATION:

Let m, n be the number of starting points and landing points. Then, the mathematical model of the soft multi-objective transportation problem is,

$$\boldsymbol{\mathcal{M}_1}: \text{Min } Z_k(e_l) = \sum_{i=1}^{m}\sum_{j=1}^{n} P_{ij}{}^{(k)}(e_l)x_{ij}(e_l), l \in \mathbb{N}$$

s.t

$$\sum_{j=1}^{n} x_{ij}(e_l) \cong a_i, i = 1,2,3, \ldots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \cong b_j, j = 1,2,3, \ldots n$$

Where$Z_k(e_l) = \{Z_1(e_l), Z_2(e_l), \ldots\ldots Z_k(e_l)\}$.

Here, $P_{ij}^{(k)}(e_l)$ denotes the crisp value connected with moving the commodities from ith starting point to jth landing point corresponding to the parameter $e_l \epsilon$ E,l$\epsilon\mathbb{N}$and to the kth objective.

When the transportation parameters are taken to be Pythagorean Trapezoidal fuzzy numbers, $\boldsymbol{\mathcal{M}_1}$ becomes a fuzzy soft multi-objective transportation problem which is represented by,

$$\boldsymbol{\mathcal{M}_2}: \text{Min } \widetilde{Z_k(e_l)} = \sum_{i=1}^{m}\sum_{j=1}^{n} \widetilde{P_{ij}^{(k)}(e_l)} x_{ij}(e_l), l \in \mathbb{N}$$

s.t

$$\sum_{j=1}^{n} x_{ij}(e_l) \cong \widetilde{a_i}\ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \cong \widetilde{b_j}\ , j = 1,2,3, \dots n$$

Here, $\widetilde{a_i}, \widetilde{b_j}$ and $\widetilde{P_{ij}^{(k)}(e_l)}$ denotes the fuzzy number with respect to the parameter in the transportation problem.

This fuzzified transportation problem is defuzzified using one of the score function of Pythagorean Trapezoidal fuzzy number**(2.6)** to obtain a deterministic model which is represented by,

$$\boldsymbol{\mathcal{M}_3}: \text{Min } \widetilde{Z_k(e_l)} = \sum_{i=1}^{m}\sum_{j=1}^{n} S(\widetilde{P_{ij}^{(k)}(e_l)}) x_{ij}(e_l), l \in \mathbb{N}$$

s.t

$$\sum_{j=1}^{n} x_{ij}(e_l) \cong S(\widetilde{a_i})\ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \cong S(\widetilde{b_j})\ , j = 1,2,3, \dots n$$

Where$S(\widetilde{P_{ij}^{(k)}(e_l)}), S(\widetilde{a_i}), S(\widetilde{b_i})$ are defuzzified values of $\widetilde{P_{ij}^{(k)}(e_l)}, \widetilde{a_i}$ and $\widetilde{b_j}$.

In this proposed model, the objectives which are optimised are as follows,

The objective function $\widetilde{Z_1(e_l)}$ denotes the fuzzy soft transportation cost & l=1,2,3 (road, rail, air)

$$\text{Min } \widetilde{Z_1(e_l)} = \sum_{i=1}^{m}\sum_{j=1}^{n} S(\widetilde{c_{ij}(e_l)})x_{ij}(e_l), l \in \mathbb{N}$$

The objective function $\widetilde{Z_2(e_l)}$ denotes the fuzzy soft transportation time w.r.t $e_l, l = 1,2,3$.

$$\text{Min } \widetilde{Z_2(e_l)} = \text{Max}\{S(\widetilde{t_{ij}(e_l)}): x_{ij}(e_l) > 0\}, l \in \mathbb{N}$$

which is the maximum time required for shipping in the active routes.

The objective function $\widetilde{Z_3(e_l)}$ denotes the fuzzy soft carbon emission cost for the distance covered in shipping.

$$\text{Min } \widetilde{Z_3(e_l)} = \sum_{i=1}^{m}\sum_{j=1}^{n} S(\widetilde{f_{ij}(e_l)})x_{ij}(e_l), l \in \mathbb{N}$$

3.2.SOLUTION APPROACHES FOR THE MULTIOBJECTIVE TRANSPORTATION PROBLEM:

3.2.1. FUZZY PROGRAMMING APPROACH(FPA):

Fuzzy optimization technique is one of the typical approach for solving the transportation problem. The fuzzy programming approach was first developed by Zimmermann (1978) which was subsequently used in the field of transportation. Attaining an optimal solution by fulfilling each of the objectives efficiently is possible only from time to time. However, a compromise solution can be acquired with the degree of satisfaction for each objective. Thus, a marginal evaluation is devised for each objective with the help of membership function. The linear membership function is

$$\mu(Z_k(u))(e_l) = \begin{cases} 1 & \text{if } Z_k(u) < L_k \\ \left(\dfrac{U_k - Z_k(u)}{U_k - L_k}\right)(e_l) & \text{if } L_k \le Z_k(u) \le U_k \\ 0 & \text{if } Z_k(x) > U_k \end{cases},$$

where U_k and L_k are lower and upper bounds for each objective function corresponding to parameter e_l. ie, $U_k(e_l) = \text{Max}[Z_k(u)](e_l) \& L_k(e_l) = \text{Max}[Z_k(x)](e_l)\ \forall\ k$. The mathematical formulation of FPA is

$$\boldsymbol{\mathcal{M}_4}: \text{Maximize } \lambda$$

s.t

$$\mu(Z_k(u))(e_l) \ge \lambda\ \forall\ k$$

$$\sum_{j=1}^{n} x_{ij}(e_l) \le S(\widetilde{a_\imath}) \ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \ge S(\widetilde{b_j}) \ , j = 1,2,3, \dots n \ \& x_{ij} \ge 0 \ \forall \ i \ \& \ j$$

3.2.2. INTUTIONISTIC FUZZY PROGRAMMING APPROACH (IFPA):

Atanassov(1986) proposed the intutionistic fuzzy set which handles membership as well as non-membership function for the components in feasible set. The mathematical expressions of the linear membership and non-membership functions under intutionistic fuzzy environment is as follows:

$$\mu(Z_k(u))(e_l) = \begin{cases} 1 & if \ Z_k(u) < L_k \\ \left(\dfrac{U_k - Z_k(u)}{U_k - L_k}\right)(e_l) & if \ L_k \le Z_k(u) \le U_k \\ 0 & if \ Z_k(x) > U_k \end{cases}$$

$$\nu(Z_k(u))(e_l) = \begin{cases} 1 & if \ Z_k(u) < L_k \\ \left(\dfrac{Z_k(u) - L_k}{U_k - L_k}\right)(e_l) & if \ L_k \le Z_k(u) \le U_k \ , \\ 0 & if \ Z_k(x) > U_k \end{cases}$$

where U_k and L_k are lower and upper bounds for each objective function corresponding to parameter e_l. ie, $U_k(e_l) = \mathrm{Max}[Z_k(u)](e_l) \& L_k = \mathrm{Max}[Z_k(x)](e_l) \ \forall \ k$. The mathematical formulation of IFPA is

$$\mathcal{M}_5 \text{: Maximize } (\lambda - \gamma)$$

s.t

$$\mu\big(Z_k(u)\big)(e_l) \ge \lambda \ \forall \ k$$

$\nu\big(Z_k(u)\big)(e_l) \le \gamma \ \forall \ k,$

where

$0 \le \lambda + \gamma \le 1; \lambda \ge \gamma \ \& \ 0 \le \lambda, \gamma \le 1$

$$\sum_{j=1}^{n} x_{ij}(e_l) \le S(\widetilde{a_\imath}) \ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \geq S(\widetilde{b_j}) \ , j = 1,2,3, \dots n \ \& x_{ij} \geq 0 \ \forall \ i \ \& \ j$$

Here, λ, γ denote the degree of satisfaction and dissatisfaction for each objective.

3.2.3. PYTHAGOREAN FUZZY PROGRAMMING APPROACH (PFPA):

Yager and Abbasov(2013)developed the Pythagorean fuzzy sets which provided greater accuracy than the intutionistic fuzzy sets. Pythagorean fuzzy sets are outspread than IFS which enables them to handle the uncertaintyin problems more precisely.

The mathematical formulation of PFPA is

$$\mathcal{M}_6: \text{Maximize } (\lambda^2 - \gamma^2)$$

s.t

$$[\mu(Z_k(u))(e_l)]^2 \geq \lambda^2 \ \forall \ k$$

$[\nu(Z_k(u))(e_l)]^2 \leq \gamma^2 \ \forall \ k,$

where

$0 \leq \lambda^2 + \gamma^2 \leq 1; \lambda^2 \geq \gamma^2 \ \& \ 0 \leq \lambda^2, \gamma^2 \leq 1$

$$\sum_{j=1}^{n} x_{ij}(e_l) \leq S(\widetilde{a_i}) \ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \geq S(\widetilde{b_j}) \ , j = 1,2,3, \dots n \ \& x_{ij} \geq 0 \ \forall \ i \ \& \ j$$

Here, λ, γ denote the degree of satisfaction and dissatisfaction for each objective.

4. CASE STUDY:

The vindication of the proposed model is done from the data collected for the distribution of a product from major Metropolitan cities in India namely Delhi, Mumbai and Chennai. The transportation cost and time for the travelling distance are cumulated from websites of transportation service agencies as mentioned in [6]. In reality, crisp value cannot be associated and so the fuzzy transportation cost forcarrying a metric tonnewith respect to the distance mentioned in Table-1 is provided.The carbon emission cost for Airways is found from theemission factors per ton per km estimated by the India GHG Program for the freight carried in passenger airlines as fuel related data is not available publically. The carbon emission cost for Railways is also found from the

India GHG Program's estimationon the emission factors per ton per km for freight transport. Meanwhile, the carbon emission cost for Roadways is found from the target diesel consumption value for commercial N3 rigid vehicles at 40km/hr instructed by the Government of India which is effective from 1st April,2021. The secondary data for the transportation time, transportation cost and carbon emission cost are taken to be Pythagorean Trapezoidal fuzzy number which are in Table-2,3 & 4.

BHOPAL			LUCKNOW			HYDERABAD			PATNA		
e1	**e2**	**e3**	**e1**	**e2**	**e3**	**e1**	**e2**	**e3**	**e1**	**e2**	**e3**
809	707	556	579	513	482	1564	1677	1230	1082	1009	856
776	843	648	1442	1428	1136	738	790	633	1802	1695	1428
1443	1505	1152	2048	2064	1447	627	789	484	2043	2344	1429

DESTINATION	**ORIGIN**	**DELHI**	**MUMBAI**	**CHENNAI**

TABLE-1: Distance between the source and destination in kms.

NATION	BHOPAL	LUCKNOW	HYDERABAD	PATNA	SUPPLY(a_i)
T.C	(5785,5789,5796, 5797);(0.9,0.1)	(3799,3806,3811, 3814);(0.9,0.1)	(9071,9072,9082, 9085);(0.9,0.1)	(6841,6848,6853, 6858);(0.9,0.2)	(12,15,19,24); (0.9,0.1)
T.T	(63,68,70,77); (0.6,0.1)	(41,48,54,58); (0.7,0.3)	(50,53,59,61); (0.9,0.4)	(52,56,62,67); (0.8,0.3)	
E.C	(17,23,27,30); (0.5,0.1)	(2,5,7,9);(0.9,0.3)	(0.9,0.1) (6561,6565,6569,	(0.8,0.1)	
T.C	(6395,6401,6404, 6412);(0.8,0.1)	(9767,9771,9779, 9786);(0.9,0.3)	(6561,6565,6569, 6572);(0.8,0.2)	(10358,10360,10362 10365);(0.9,0.1)	(15,18,22,25); (0.9,0.4)
T.T	(62,67,71,77); (0.6,0.2)	(40,44,46,51); (0.9,0.1)	(42,44,46,48); (0.7,0.2)	(45,47,53,55); (0.9,0.2)	
E.C	(12,15,19,23); (0.6,0.2)	(10,12,15,17); (0.9,0.2)	(16,18,21,24); (0.6,0.3)	(13,14,18,19); (0.9,0.1)	
T.C	(9078,9082,9084, 9089);)(0.9,0.2)	(11079,11080,11082, 11084);(0.9,0.1)	(6964,6966,6972, 6973);(0.7,0.1)	(12285,12290,12294,1 2297);(0.9,0.3)	(34,39,43,44); (0.7,0.3)
T.T	(51,55,59,64); (0.9,0.4)	(55,59,64,68); (0.9,0.1)	(35,39,41,47); (0.8,0.2)	(70,75,79,83); (0.9,0.3)	
E.C	(9,13,15,17); (0.9,0.2)	(12,15,19.5,22); (0.9,0.1)	(8,10,13,15); (0.8,0.5)	(13,17,20,26); (0.9,0.2)	
DEMAND(b_j)	(10,14,17,19); (0.8,0.2)	(16,23,29,32); (0.8,0.4)	(9,11,14,16); (0.9,0.1)	(15,17,23,25); (0.8,0.2)	

SOURCE	NATI	BHOPAL	LUCKNOW	HYDERABAD	PATNA	SUPPLY(a_i)
DELHI	T.C	(4091,4099,4105, 4111);(0.8,0.1)	(6858,6864,6866, 6872);(0.7,0.3)	(2272,2275,2278, 2282);(0.9,0.2)	(4695,4705,4712, 4716);(0.9,0.3)	(12,15,19,24); (0.9,0.1)
	T.T	(30,35,39,41); (0.7,0.1)	(23,24,26,28); (0.8,0.2)	(38,40,44,46); (0.9,0.3)	(40,43,46,49); (0.7,0.1)	
	E.C	(1,2,3,4);(0.9,0.1)	(1,2,4,5);(0.7,0.1)	(5,6,6,11);(0.8,0.2)	(1,3,6,7);(0.9,0.4)	
MUMBAI	T.C	(3825,3827,3830, 3833);(0.9,0.1)	(4319,4325,4329, 4331);(0.9,0.2)	(3809,3814,3817, 3820);(0.8,0.2)	(5447,5450,5453, 5456);(0.9,0.3)	(15,18,22,25); (0.9,0.4)
	T.T	(28,30,33,37); (0.8,0.1)	(41,43,45,47); (0.9,0.4)	(23,26,32,35); (0.9,0.2)	(50,54,57,60); (0.8,0.3)	
	E.C	(3,6,9,10);(0.7,0.4)	(4,7,11,13);(0.8,0.5)	(3,5,7,10);(0.6,0.1)	(4,6,10,11);(0.8,0.2)	
CHENNAI	T.C	(5739,5741,5745, 5747);(0.9,0.4)	6278);(0.8,0.1)	(3836,3841,3845, 3849);(0.9,0.2)	(5810,5814,5819, 5822);(0.9,0.1)	(34,39,43,44); (0.7,0.3)
	T.T	(41,44,49,52); (0.9,0.1)	(48,51,53.54); (0.9,0.4)	(25,26,28,31); (0.9,0.2)	(65,68,71,73); (0.7,0.1)	
	E.C	(3,6,8,9); (0.9,0.4)	(6,7,10,14);(0.8,0.3)	(1,4,6,7);(0.7,0.1)	(4,8,10,11);(0.9,0.3)	
	DEMAND(b_j)	(10,14,17,19); (0.8,0.2)	(16,23,29,32); (0.8,0.4)	(9,11,14,16); (0.9,0.1)	(15,17,23,25); (0.8,0.2)	

TABLE-2: Fuzzy Transportation cost(T.C), Transportation time(T.T), Emission cost w.r.t e1=roadways.

TABLE-3: Fuzzy Transportation cost(T.C), Transportation time (T.T), Emission cost(E.C) w.r.t e2=railways.

SOURCE	LUCKNOW	HYDERABAD	PATNA	SUPPLY(a
DELHI	(4885,4891,4894, 4900);(0.8,0.4)	(4444,4451,4455, 4458);(0.9,0.1)	(6409,6416,6422, 6426);(0.8,0.1)	(12,15,19,2 (0.9,0.1)
	(1,4,5,8);(0.7,0.4)	(2,6,9,12);(0.8,0.4)	(1,5,7,10);(0.8,0.5)	
	(262,270,275,281); (0.9,0.2)	(384,389,393,394); (0.9,0.1)	(666,673,681,686); (0.8,0.3)	
MUMBAI	(6853,6861,6867, 6875);(0.9,0.3)	(4041,4048,4052, 4055);(0.8,0.2)	(8289,8293,8299), 8303);(0.9,0.1)	(15,18,22,25); (0.9,0.4)
	(3,6,9,11);(0.9,0.3)	(1,3,6,8);(0.9,0.1)	(1,4,6,10);(0.9,0.4)	
	(720,727,731,734); (0.8,0.1)	(286,290,296,300); (0.9,0.3)	(944,952,959,963); (0.9,0.4)	
CHENNAI	(8686,8690,8694, 8698);(0.9,0.2)	(5022,5027,5032, 5037);(0.7,0.1)	(9189,9193,9200, 9207);(0.9,0.3)	(34,39,43,44); (0.7,0.3)
	(4,7,8,11);(0.8,0.3)	(1,4,9,15);(0.8,0.6)	(9,12,19,23); (0.7,0.4)	
	(778,785,790,792); (0.9,0.1)	(526,538,544,551); (0.8,0.6)	(1022,1034,1039, 1044);(0.8,0.2)	
	(16,23,29,32); (0.8,0.4)	(9,11,14,16); (0.9,0.1)	(15,17,23,25); (0.8,0.2)	

DESTINATION		**BHOPAL**
SOURCE		
DELHI	**T.C**	(4864,4869,4872,4875);(0.8,0.3)
	T.T	(1,2,5,6);(0.7,0.3)
	E.C	(369,377.390,399);(0.8,0.1)
MUMBAI	**T.C**	(4040,4042,4045,4049);(0.9,0.2)
	T.T	(7,9,13,16);(0.8,0.6)
	E.C	(577,583,589,596);(0.7,0.1)
CHENNAI	**T.C**	(4911,4917,4924,4928);(0.8,0.1)
	T.T	(2,7,11,14);(0.8,0.2)
	E.C	(619,624,627,634);(0.7,0.1)
DEMAND(b_j)		(10,14,17,19);(0.8,0.2)

TABLE-4: Fuzzy Transportation cost(T.C), Transportation time (T.T), Emission cost w.r.t e3=airways

Using $\boldsymbol{\mathcal{M}_3}$,

We find that the given problem is a balanced transportation problem.

The three objectives w.r.t e1 = Roadways are,

$$\mathrm{MinZ_1} = 4170.06x_{11} + 3046x_{12} + 7263x_{13} + 5274.5x_{14} + 4033.89x_{21} + 7038.54x_{22} + 3940.05x_{23} + 8289x_{24} + 6994.1025x_{31} + 8865x_{32} + 3345x_{33} + 8849.88x_{34}$$

$$\mathrm{MinZ_2} = \{\max t_{ij} : x_{ij} > 0\}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}x_{ij} = 24.325x_{11} + 20.1x_{12} + 36.2375x_{13} + 36.2375x_{14} + 22.16x_{21} + 36.2x_{22} + 20.25x_{23} + 38.5x_{24} + 37.2125x_{31} + 49.2x_{32} + 24.3x_{33} + 55.26x_{34}$$

$$\mathrm{Min}Z_1 = 5.82x_{11} + 4.14x_{12} + 11.2x_{13} + 7.875x_{14} + 5.52x_{21} + 10.395x_{22} + 5.3325x_{23} + 12.8x_{24} + 10.395x_{31} + 13.7x_{32} + 4.485x_{33} + 14.63x_{34}$$

s.t$x_{11} + x_{12} + x_{13} + x_{14} = 14$

$x_{21} + x_{22} + x_{23} + x_{24} = 13$

$x_{31} + x_{32} + x_{33} + x_{34} = 16$

$x_{11} + x_{21} + x_{31} = 9$

$x_{12} + x_{22} + x_{32} = 12$

$x_{13} + x_{23} + x_{33} = 10$

$x_{14} + x_{24} + x_{34} = 12$

On solving thisformulation using the LINGO program, we get

$$L_1(e_1) = 2{,}03{,}111.3, U_1(e_1) = 2{,}17{,}507.285; L_2(e_1) = 38.5, U_1(e_1) = 55.26; L_3(e_1) = 298.94, U_3(e_1) = 317.21$$

where $L_k(e_1) \& U_k(e_1), k = 1,2,3$ denotes the lower bound and upper bound for the kth objective corresponding to the parameter e1=Roadways.

Then, we take the membership function defined in section **3.2** to get the optimal compromise solutionusing FPA($\mathcal{M}_4$),IFPA($\mathcal{M}_5$) and PFPA($\mathcal{M}_6$)

With $\mathcal{M}_4$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 8, x_{13} = 0, x_{14} = 6, x_{21} = 8, x_{22} = 1, x_{23} = 2, x_{24} = 2, x_{31} = 1,$$
$$x_{32} = 3, x_{33} = 8, x_{34} = 4,$$
$$\lambda = 1, \mu = 0, Z_1(u)(e_1) = 2{,}15{,}531.3825, Z_2(u)(e_1) = 55.26, Z_3(u)(e_1) = 317.085$$

With $\mathcal{M}_5$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 8, x_{13} = 0, x_{14} = 6, x_{21} = 9, x_{22} = 1, x_{23} = 2, x_{24} = 1, x_{31} = 1,$$
$$x_{32} = 3, x_{33} = 8, x_{34} = 4,$$
$$\lambda = 1, \mu = 0, Z_1(u)(e_1) = 2{,}13{,}132.05, Z_2(u)(e_1) = 55.26, Z_3(u)(e_1) = 314.04$$

With $\mathcal{M}_6$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 11, x_{13} = 0, x_{14} = 3, x_{21} = 9, x_{22} = 0, x_{23} = 0, x_{24} = 4, x_{31} = 0,$$
$$x_{32} = 1, x_{33} = 10, x_{34} = 5,$$
$$\lambda = 1, \mu = 0, Z_1(u)(e_1) = 2{,}05{,}354.91, Z_2(u)(e_1) = 55.26, Z_3(u)(e_1) = 301.745$$

Similarly, we find the objectives corresponding to e2 = Railways and e3 = Airwaysusing $\mathcal{M}_3$and solve them in LINGO(19.0) to get,

$$L_1(e_2) = 140156.8, U_1(e_2) = 140504.6; L_2(e_2) = 33.24, U_1(e_2) = 37.2;$$
$$L_3(e_2) = 121.89, U_3(e_2) = 123.21$$

$$L_1(e_3) = 1{,}54{,}714.1, U_1(e_3) = 1{,}82{,}571.43; L_2(e_3) = 4.13, U_1(e_3) = 5.18;$$
$$L_3(e_3) = 14102.7, U_3(e_3) = 16798.8$$

Taking the membership function defined in section **3.2**, we get the optimal compromise solution for FPA($\mathcal{M}_4$),IFPA($\mathcal{M}_5$) and PFPA($\mathcal{M}_6$).

For e2 = Railways,

With $\mathcal{M}_4$**,** the optimal solution is

$x_{11} = 0, x_{12} = 9, x_{13} = 5, x_{14} = 0, x_{21} = 7, x_{22} = 2, x_{23} = 3, x_{24} = 1, x_{31} = 2,$
$x_{32} = 1, x_{33} = 2, x_{34} = 11,$

$$\lambda = 1, \mu = 0, Z_1(u)(e_2) = 1{,}40{,}893.51, Z_2(u)(e_2) = 37.2, Z_3(u)(e_2) = 158.13$$

With $\mathcal{M}_5$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 3, x_{13} = 0, x_{14} = 11, x_{21} = 4, x_{22} = 6, x_{23} = 3, x_{24} = 0, x_{31} = 5,$$
$x_{32} = 3, x_{33} = 7, x_{34} = 1,$

$$\lambda = 1, \mu = 0, Z_1(u)(e_2) = 1{,}45{,}351.41, Z_2(u)(e_2) = 37.2, Z_3(u)(e_2) = 133.97$$

With $\mathcal{M}_6$**,** the optimal solution is

$x_{11} = 0, x_{12} = 12, x_{13} = 0, x_{14} = 2, x_{21} = 9, x_{22} = 0, x_{23} = 0, x_{24} = 4, x_{31} = 0,$
$x_{32} = 0, x_{33} = 10, x_{34} = 6,$

$$\lambda = 1, \mu = 0, Z_1(u)(e_2) = 1{,}40{,}504.6, Z_2(u)(e_2) = 33.24, Z_3(u)(e_2) = 121.89$$

For e3 = Airways,

With $\mathcal{M}_4$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 7, x_{13} = 7, x_{14} = 0, x_{21} = 6, x_{22} = 4, x_{23} = 2, x_{24} = 1, x_{31} = 3,$$
$$x_{32} = 1, x_{33} = 1, x_{34} = 11,$$
$$\lambda = 0.2085714, \mu = 0, Z_1(u)(e_3) = 1{,}82{,}565.33, Z_2(u)(e_3) = 5.22,$$
$$Z_3(u)(e_3) = 16{,}785.89$$

With $\mathcal{M}_5$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 7, x_{13} = 7, x_{14} = 0, x_{21} = 6, x_{22} = 4, x_{23} = 2, x_{24} = 1, x_{31} = 3,$$

$$x_{32} = 1, x_{33} = 1, x_{34} = 11,$$

$$\lambda = 0.2085714, \mu = 0, Z_1(u)(e_3) = 1{,}82{,}565.33, Z_2(u)(e_3) = 5.22,$$

$$Z_3(u)(e_3) = 16{,}785.89$$

With $\boldsymbol{\mathcal{M}_6}$**,** the optimal solution is

$$x_{11} = 0, x_{12} = 5, x_{13} = 0, x_{14} = 9, x_{21} = 9, x_{22} = 0, x_{23} = 0, x_{24} = 3, x_{31} = 0,$$

$$x_{32} = 7, x_{33} = 9, x_{34} = 0,$$

$$\lambda = 1, \mu = 0, Z_1(u)(e_3) = 1{,}67{,}074.66, Z_2(u)(e_3) = 4.13, Z_3(u)(e_3) = 15{,}298.9$$

5.CONCLUSION:

This paper investigated a fuzzy soft multi-objectivetransportation problem with environmental benefits.For the proposed model, we have found the optimal compromise solution with three approaches namely FPA,IFPA and PFPA. In the illustration, the transportation cost, transportation time and carbon emission cost for the distance covered via roadways, railways and airways are minimised. Among the three solution approaches, we observe that the solution obtained from Pythagorean Fuzzy Programming Approach(PFPA) is minimum for all the three parameters e1,e2 and e3. Finally, the decision maker can choose his or her own choice among the three modes of transportation depending upon their priorities like saving time, friendly budget, green environment and so on.We have constructed a model utilising single mode of transportation between the sources and destinations. But,more than one mode of transportationcan be availed between the supply and demand points and so we can extend this model for the desired mode choices preferable as well as for the combination of modeswhich generates a multimodal transportation problemgiving more effective solution.We can also use this model for various other uncertain transportation environmentwith different parameters.

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